Using Social Media for Crisis Response : The ATHENA System

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Using Social Media for Crisis Response: The ATHENA System

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Abstract: Social media is now prevalent in all aspects of society. Any major news event is now accompanied by a stream of real-time social media posts. The ATHENA system turns this stream of information into a vital resource in crisis and disaster response for Law Enforcement Agencies (LEAs). The ATHENA system scans the social media environment during a crisis, recognises and collects information relevant to the crisis, and synthesises that information into credible and actionable reports. Via an automated process of classification, these reports are delivered by ATHENA to the stakeholders that most need the information: from the LEA Command and Control Centre managing the crisis, to the first responders on the ground, and to the citizens themselves via a mobile application. The automatic extraction of location data from social media posts allows ATHENA to pin-point crisis activity and resources on a map-based user interface. The citizen, via a mobile device, is provided with fast and reliable alerts of danger, the location of medical help and vital supplies, and direct communication with emergency services. The first responder is given the same intelligence along with additional information pertinent to their search and rescue actions. Command and Control have the ultimate access to all information being processed by the system, where their decision making is supported by computer generated estimates of priority and credibility. Command and Control have the responsibility of validating crisis information before it is disseminated to the public. Social media are also key to the dissemination of crisis information. Dedicated social media entities on the most popular sites are maintained by Command and Control to provide a focal information, advice and instruction broadcasting presence as a trusted source. These social media presences are designed to encourage collaboration between the public and first responders and to provide a channel for communication between all the crisis stakeholders. Thus ATHENA empowers the LEA and the public with a collective intelligence, enabling both to safeguard themselves and others during a crisis.

Keywords: social media, crisis response, ATHENA system

1. Introduction

The use of social media continues to increase, this fuels a growing market of applications that utilise social media data. Social media can act as a broadcast medium (Burke et al., 2011); services like Twitter are used by traditional journalists to report news stories but just as often it is ordinary citizens who are posting breaking news themselves. The speed at which this information travels and propagates across networks means the time from an incident occurring to millions of people knowing about it has never been shorter, and sometimes even ahead of official sources (Hu et al., 2012). The first minutes of a crisis are critical and now obtaining first hand witness reports has never been easier. This information is often immediately broadcast on social media but the challenges lie in how to manage these vast quantities of data, extract reliable and actionable intelligence and channel that information towards the right people and in a timely manner.

To face these challenges we propose the ATHENA system. ATHENA brings together stakeholders including law enforcement agencies (LEAs), first responders and citizens and caters to each of these stakeholders' needs during a crisis. It obtains and processes social media data and presents it to LEAs for situational awareness, it engages citizens, via a mobile application, allowing them to send reports directly to ATHENA, LEAs then view these reports from social media on a crisis dashboard which completes the loop by allowing LEAs re-publish this information on a mobile crisis map and dedicated social media channels therefore maintaining a strong link between LEAs and the public that promotes trust and confidence in their handling of the crisis.

In this paper we present work relating to the use of social media during crisis situations in Section 2, an introduction to the ATHENA system and the requirements gathering process in Section 3, Sections 4, 5 and 6 then present the data processing phase, the crisis dashboard components and the mobile application of the ATHENA system.

2. Related work

The use of social media in crises has already been explored in a variety of crisis situations including hurricanes (Imran et al., 2013), earthquakes (Yates & Paquette, 2011) , floods (Bird et al., 2012), the riots in London in 2011 (Denef et al., 2013), and the aftermath of the Boston (USA) Bombings (Cassa et al., 2013). The public now expect the use of social media during a crisis by emergency response organisations (Abbasi et al., 2012). However, communication is often ad-hoc and not linked up to other social media data and intelligence. ATHENA streamlines this communication process by using social media for situational awareness and as a platform to communicate with the public.

Twitter is a crucial source of real time crisis information and, although Twitter itself is not a good platform for crisis management (Goolsby, 2010), the information posted on Twitter is valuable hence the continuing efforts to collect and organise that information in a meaningful way. A good example of LEA use of social media was the 2011 Queensland (Australia) Floods. The @QPSMedia (Queensland Police Service) Twitter account became a trusted source for situational information while the #qldflood hashtag generated discussion and support for the coordination fundraising and relief efforts (Bruns et al., 2012). However, this style of linear communication relies on having the manpower to read and respond to each post. ATHENA processes this information automatically and provides aggregated reports to those in the communication hub via an intuitive dashboard display expediting the verification process.

Platforms using crowd-sourced information during crises tend to fall into two categories: the use of social media by crisis management organisations to coordinate the crisis response or the use of crowd-sourcing for assistance and support during a crisis (Latonero & Shklovski, 2011). However, there are few platforms focused on marrying the two together; this is one of the fundamental goals of ATHENA.

Existing crisis response platforms include the humanitarian response application Ushahidi (2014) which features social media integration and the stand-alone applications Crowdmap and SwiftRiver that provide further mapping and data analysis functionalities. An issue with user generated reports is how to classify their content. The MicroMappers app (Meier et al., 2014; MacKenzie, 2013) aims to overcome this issue by using volunteers to classify tweets manually. AIDR (Artificial Intelligence for Disaster Response) (Imran et al., 2014) extends this idea by using machine learning for automatic classification. EmergencyAUS (http://www.emergencyaus.info/) is an Australian mobile and web based crisis map and alerting system that uses official sources and user reports while FEMA (Federal Emergency Management Agency) (https://www.fema.gov/mobile-app) has an app for America with crisis information and citizen reporting features. Google (2014) also offers crisis response functionalities and integration of Twitter with Google Now (Honan, 2014) to provide relevant crisis tweets. The ATHENA mobile application consists of a crisis map alongside direct reporting features. The CCCID also incorporates a verification process meaning that only accurate information reaches citizens.

Some systems integrate directly with LEA workflows. Razip et al.'s (2014) visual analytics application assists LEAs in their daily roles by mapping crime incidents and risk profiles but it also includes functionality for first responders; an example being chemical plume modelling to monitor and control crowds during chemical spills. Kim et al.'s (2008) mobile interface for first responders in emergency situations displays locations of team members, first responders, and hot zones while Yin et al. (2012) monitor tweets in real-time employing text analytics techniques to identify bursts of activity, mapping and visualisation. However, none of these systems bring LEAs together with the public and social media data during a crisis. The advantage of ATHENA is that it integrates with LEAs in command and control, offering reporting and maps for first responders, gathering eyewitness reports from social media and engaging the public through crisis reporting and monitoring features.

3. ATHENA overview

3.1 The ATHENA system

The vision for the ATHENA system (Andrews et al., 2013), as shown in Figure 1, is to source data from social media sites and a dedicated crisis mobile application to provide real-time information to LEAs and first responders. That is, to scan the social media environment, recognise relevant information, analyse and synthesise this data into credible reports which are directed to LEAs for verification and dissemination to the public. This system provides situational awareness for LEAs and first responders and gives citizens the power to contribute to the crisis effort.

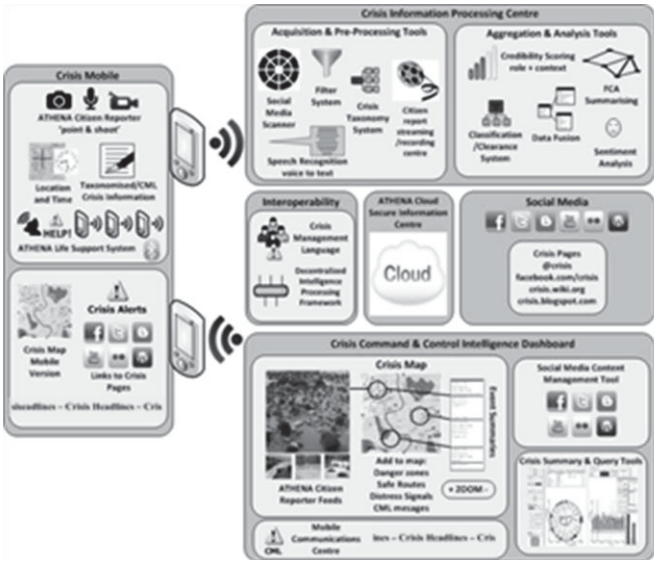

Figure 1: The ATHENA vision

The ATHENA system has three main components:

- information processing - to collect and analyse relevant crisis data
- command and control dashboard - a user interface monitored by LEAs to view, verify and query crisis data, and communicate with the public,
- mobile application - a application for citizens and first responders with mapping and reporting features

3.2 Requirements gathering

Based on the ATHENA vision a series of requirements gathering exercises were undertaken by our end-user partners including West Yorkshire Police (UK), the Municipality of Ljubljana (Slovenia) and Izmir (Turkey). These comprised of questionnaires and individual workshops to extract their current practices of working with social media, their crisis response mechanisms, and their initial requirements for an ATHENA system. The results of these workshops and questionnaires were then fed back to the technical team who proceeded to construct mock-ups of the mobile application and the crisis dashboard alongside a tentative list of potential user requirements. These were then presented to the end users in a two day workshop to comment on their functionality and how essential they considered each function to be. Following this workshop an initial set of requirements were distilled and distributed to the technical teams to begin development of the initial prototypes. As the prototypes are evaluated the feedback will be incorporated in to the requirements list for the next phase of development. The first iteration of the requirements are represented in the prototypes presented in Sections 5 and 6 of this paper.

3.3 User tiers and permissions

A further outcome from the workshops was the concept of user tiers: different users should have different levels of permissions. A three tier system was proposed with tier 1, tier 2 and public users. Tier 1 users are those in the command and control centre while tier 2 users are first responders, credible community members, local government and critical infrastructure providers. These permissions control what information is available to the user so public users cannot see unverified or operational information.

4. Crisis information processing

The crisis information processing centre (CIPC) is the data-focused component of the ATHENA system. The CIPC is responsible for obtaining data from social media and mobile reports and then filtering, processing, analysis and aggregating this data into a format that can be incorporated into the dashboard.

4.1 Crawling social media

Alongside mobile reports, data from social media is the other key information resource for the ATHENA system. This data is obtained by crawling sites such as Twitter and Facebook using a controlled vocabulary, including hashtags and keywords, to identify relevant posts. A tweet may include text, images, videos, hyperlinks and hashtags as well as metadata including geo-location, timestamp and number of retweets or favourites. Similar data can also be obtained from Facebook; however, access to data from both services depends on user's own privacy settings.

ATHENA uses SAS's Information Retrieval Studio (IRS) to access the Twitter and Facebook APIs. The advantage of using IRS is its integration with the information processing pipeline that supports filtering, categorisation, concept extraction and sentiment analysis. IRS's extensible plugin architecture also means new functionality can be added as necessary.

4.2 Categorisation and contextual extraction

Free text data is difficult to extract meaning from thus natural language processing techniques must be employed in order to make sense of unstructured text sources. The foundation for this sense-making is a comprehensive crisis taxonomy designed to aid understanding of crisis events from brief social media posts. This is implemented as two strands in the taxonomy: one for categorisation and the other for concept and contextual extraction. This is the first step in the ATHENA information processing pipeline.

4.2.1 Categorisation

Categorisation is the process of analysing a document's content and applying a category. In order to achieve situational awareness from social media we must be able to extract information about their content. Olteanu, Vieweg and Castillo (2015) have used a machine learning approach to extract information across different crisis dimensions while here we use a rule based method to define categories. Documents (social media posts and mobile reports) can belong to multiple categories if their content matches multiple rules. The top tier of the taxonomy contains the broad categories Attack, Crash, Hazard, Health, Natural Disaster, Public Order Incidents, Terrorism and Other which are then sub-divided into further categories as shown in Figure 2.

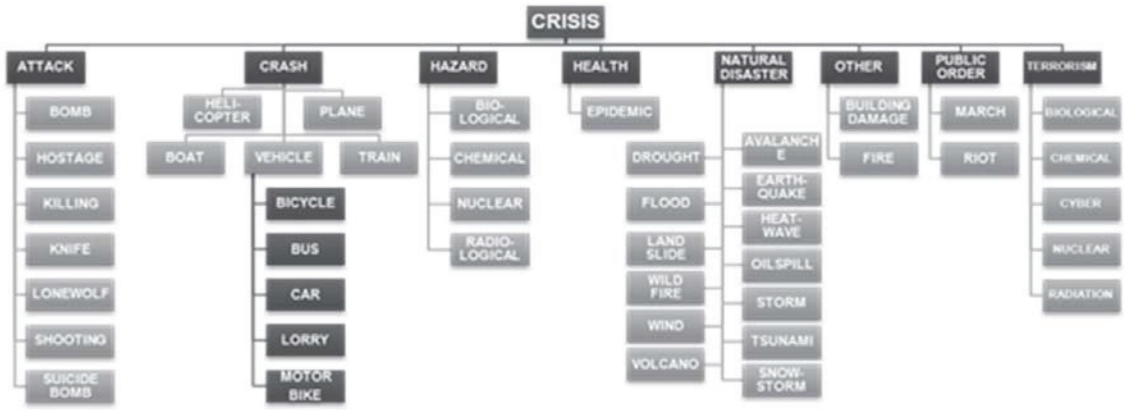

Figure 2: ATHENA categorisation taxonomy

Each category is defined by a series of rules that describe the components of each crisis scenario. These rules can use Boolean statements, particular sentence constructs such as word distance and order, alongside a controlled vocabulary of terms related to the category.

For example, based on the simple report:

> *"There's been an incident at Buca junction. Multiple cars have crashed"*

Two categories are matched, these are:

- CRISIS/CRASH/CRASH-VEHICLE;
- CRISIS/CRASH/CRASH-VEHICLE/CRASH-CAR

The first match corresponds to the first sentence while the second match corresponds to the second sentence. These categories are then used for further processing and aggregation within the CIPC.

4.2.2 Concept and contextual extraction

Concept and contextual extraction is the process of identifying specific entities contained within the document which may be keywords, sentence constructs or relationships defined by Boolean rules. However, rather than applying an overall category to the data, small fragments of information are extracted. As Tanev, Piskorski and Atkinson (2008) put it the aim is to extract 'who did what to whom, when, with what methods, where and eventually why?'.

Concept extraction is used to identify synonyms or related terms to provide consistency. For example, given the concept earthquake, matching terms may include earthquake(s), seismic activity, tremor(s), aftershock(s), epicentre, epicenter and Richter scale. Any occurrence of these terms matches the earthquake concept.

Contextual extraction goes one step further by identifying relationships between concepts and then extracting them. For example, to extract the location of an earthquake both the earthquake concept and a location must be co-located within the same sentence. These rules can be made more complex by adding additional qualifiers and ordering constraints. Figure 3 shows how the concepts are extracted. Three individual concepts are extracted and a further concept <earthquake-loc> indicates that an earthquake has been detected alongside a location, in this case Izmir and Bornova.

4.3 Crisis concepts

Crisis concepts convert the output from categorisation and contextual extraction into structured data. This data is then processed, sent to the CCCID and subsequently placed on the crisis map or used for further analysis such as visualisations, queries and filtering. Crisis concepts are created through a data analysis technique known as Formal Concept Analysis (FCA) (Ganter & Wille, 1999). FCA is a hierarchical classification method that classifies large amounts of data in to different groups depending on its properties (known as attributes). FCA has been used successfully in the past to classify data relating to the mouse embryos (Andrews & McLeod, 2011), linguistic features (Priss, 2005) and market intelligence (Andrews & Orphanides, 2013). Here FCA is used to aggregate crisis information and prevent information overload on the crisis map. Each post constitutes one item of data and its attributes are the concepts and categories. A characteristic of social media data is the similarity of posts about the same event therefore by combining FCA with categorisation and contextual extraction data can be quickly aggregated which in turn acts as a corroboration method and reduces the number of similar reports passed to the CCCID helping to streamline the verification processes.

```
<?xml version="1.0" encoding="utf-8"?>

<article>

        <text>earthquake from izmir can be felt in bornova</text>

        <tag>natural disaster</tag>

        <earthquake-loc>bornova; izmir</earthquake-loc>

        <subject>Bornova Earthquake</subject>

        <latitude>38.464572</latitude>

        <longitude>27.217967</longitude>

        <concepts>
```

Figure 3: Example of extracted concepts from a mobile report

Figure 4 shows an example crisis concept from a fictional earthquake scenario set in Izmir. These sources mention people are trapped and further location information: the people are trapped in a house in Balcova. This data can then be incorporated into reports which can then be added to the crisis map.

```
"CrisisConceptId" : 23,
      "attributes" : {
            "events": [
                {
                    "event":"ppltrapped",
                    "loc": ["house","balcova"]
                 ],
             "tag": ["medical"],
             "categories": []
      },
      "frequency" : 2,
      "sources" : ["izmir081","izmir083"]
```

Figure 4: An example of a crisis concept which is corroborated by two separate sources

5. Command and control centre intelligence dashboard (CCCID)

The CCCID is the hub of all ATHENA operations. Data from mobile report and social media is processed by the CIPC and then presented to command and control via the crisis map and visualisations as part of the dashboard. Each report is verified before being posted to the public version of the crisis map; this process is shown in Figure 5. The dashboard also facilitates communication with the public by allowing a CCCID user to post message to ATHENA's dedicated social media channels.

Figure 5: Process from report submission to validation

5.1 Crisis map

Crisis mapping is now emerging as a field in its own right (Ziemke, 2012). In a crisis Meier (2012) describes having a crisis map as 'your own helicopter' providing real-time situational awareness about the unfolding crisis. Therefore a crisis map is an essential component of the ATHENA dashboard. The crisis map displays all geo-located information, such as mobile reports, aggregated social media posts and important locations. Goolsby (2010) proposed the idea of a multilayer, interagency map showing different information to different levels of users. Through the trusted user system ATHENA will implement these privacy levels on the both CCCID map and the mobile map to restrict what different users can see. The requirements gathering process identified a number of functionalities for the crisis map including pan/zoom, view reports and mark them as read/unread, validated/rejected, to add/delete reports, to change a report's category, add importation location pins and to show priority and credibility levels. The map also has faceted search functionality. An initial prototype has been constructed that demonstrates this functionality using simulated mobile reports.

5.2 Crisis symbology

For the CCCID and mobile crisis maps a crisis symbology has been developed to allow users to quickly identify specific events occurring during the crisis. Having a clear consistent and concise symbology is necessary so that users can easily interpret them even in high-pressure and stressful situations (Akella, 2009). A report pin indicates the location of a report. Each pin may represent a single report or a number of aggregated reports about the same incident. An important location pin indicates specific locations such as hospitals, police stations, medical equipment and other supplies. A set of 11 symbols (Figure 6) have been designed to indicate categories on the crisis map. Many of these symbols come from OCHA's (OCHA, 2012) humanitarian icons.

5.2.1 Faceted map search

The crisis map implements faceted search for filtering of the information shown on the map's display. They filters include:

- filter by validated/unvalidated/rejected reports
- filter by read status

- filter by priority level.

Each of these filters can be combined so that users can, for example, filter to see only unvalidated reports that have a high priority level. Future iterations will include a free text search over the reports, filtering by category, credibility and user tier. Figure 7 shows the crisis map with unvalidated reports and the information window that appears when a report is selected.

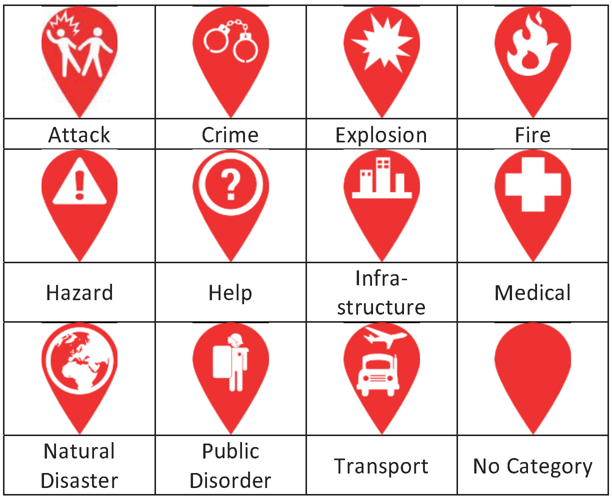

Figure 6: Crisis symbols

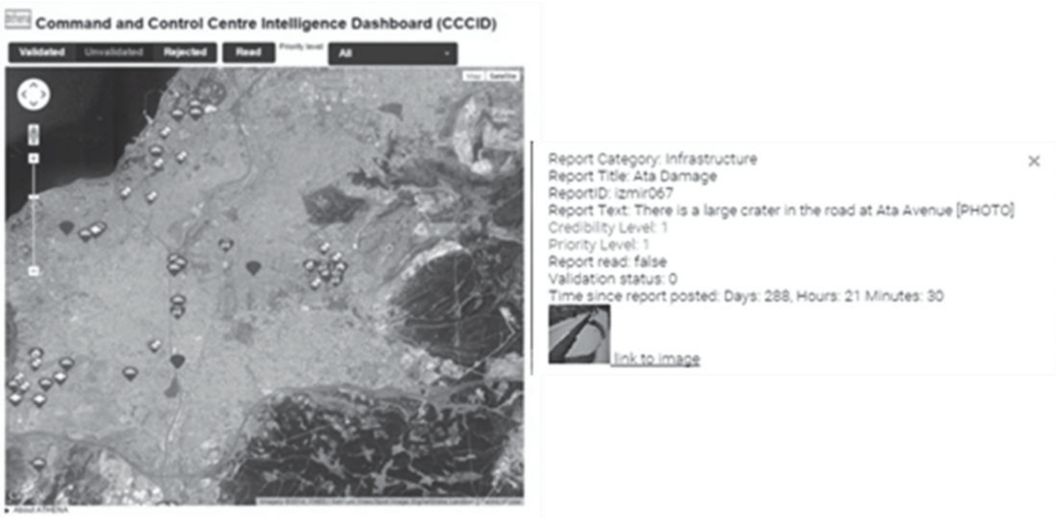

Figure 7: The figure on the left shows the crisis map with all unvalidated reports while the right figure shows an example report window

5.2.2 Updating and verifying crisis information

A CCCID user has the power to update reports including changing the validation status, annotating the location, updating the user tier level or adding more information to the report text. During our user workshops a requested feature was a 'read' status which would form part of an LEA's audit trail for a post incident review. Figure 8 shows the information window where users can change the validated/unvalidated and the read/unread statuses.

5.3 Mobile communication centre

The mobile communication centre controls all communication in and out of the ATHENA system between the public, first responders and LEAs. The communication centre contains the news list-style presentation of the reports displayed on the crisis map and supports report creation. The mobile communication centre also pushes out information to the mobile application by populating the headline banner and ATHENA's dedicated social media pages ensuring the public are engaged with ATHENA.

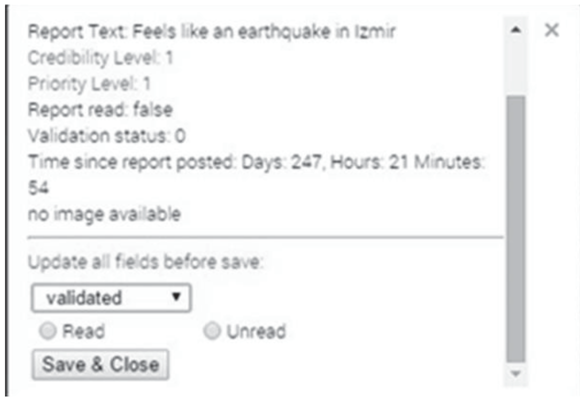

Figure 8: Information window showing how users can mark items as validated/unvalidated/rejected and as read/unread

5.4 Crisis summary and query tools

The crisis summary and query tools comprise of interactive crisis visualisations such as word clouds, charts, graphs and filterable tables. These tools allow CCCID users to query data not appropriate for presentation via the crisis map so that CCCID users can identify trends and patterns in the crisis data to assist the crisis response.

6. Mobile application

A smartphone application is another mode besides social media for citizens and first responders to track and report about the current crisis. Information provided through a dedicated mobile application may be considered more trustworthy than data mined from social media and even more so if the user opts to add additional personal information to the app (Weaver et al., 2012). The ATHENA mobile application facilitates communication with the public and first responders via a crisis map, news list and headline banner. It involves the citizen by allowing them to send reports to ATHENA as text, video and images. The application supports both public users and verified trusted users and the content displayed depends on their status. Users can store emergency contact information and have one touch emergency calls and notifications about nearby crisis events.

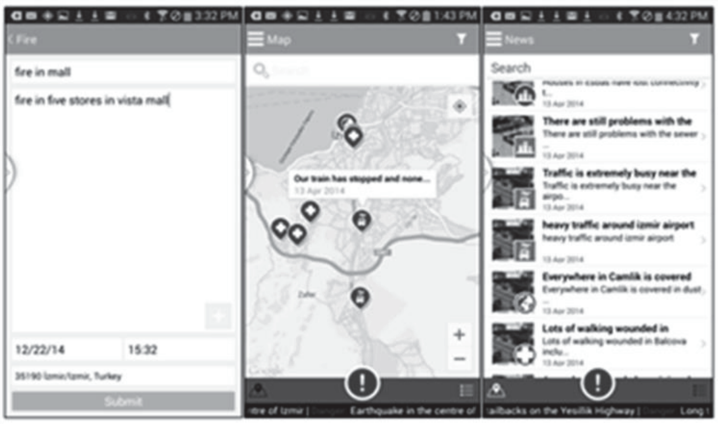

Figure 9: ATHENA mobile application showing citizen reporting interface, the mobile crisis map and news feed

6.1 Making a report

ATHENA aims to take advantage of citizens' willingness to help during a crisis. The reporting features allow citizens and first responders to send information directly to ATHENA where it is processed along with other crisis data. When a user chooses to make a report they enter a subject and a textual report and a category. Images, videos or audio files can also supplement their report. This report then goes to the CIPC for processing (for example, to be aggregated with similar reports), before being posted to the CCCID map where it is verified. The prototype reporting interface is show in Figure 9.

6.2 Mobile crisis map

The mobile crisis map (centre image of **Figure 9**) mirrors the functionality of the CCCID map and adheres to the user tiers, thus public users only see public reports but trusted user see additional information. The map uses the same crisis symbology as the CCCID map to display incidents and offers the ability add and select 'My Important Locations' (locations that users wish to highlight with additional pins). Clicking on each pin also brings up an information bubble containing a title, date, category and further incident details. Reports can also be filtered based on this information.

7. Conclusions

In this paper we have presented an introduction to the initial prototypes of the ATHENA system based on our first round of user requirements gathering. We have demonstrated how we plan to bring together citizens, first responders and LEAs by creating a system that each user invests in by contributing their own data. This in turn leads to a system that is built upon an ever more comprehensive data source making the situational awareness provided by the system richer and more complete. The system is comprised of three main strands: data processing, command and control dashboard and mobile application. These three strands are tightly integrated meaning that ATHENA will provide a comprehensive crisis management platform for LEAs, first responders and citizens. The next stages will involve evaluating the feedback from our end users on these initial prototypes, re-assessing the requirements list and developing these into a first version of an integrated system ready for a live exercise user testing scenario.

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